CEMENT
AND
CEMENT MANUFACTURE

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The Hardening and Corrosion of Cement—I.

By Dr. KARL E. DORSCH

(OF THE TECHNICAL HIGH SCHOOL, BADEN).

The Hydration of Portland and Aluminous Cements.

IN this series of articles the author will describe his recent physico-chemical researches on the setting, hardening and corrosion of cements. It first of all appeared desirable to attempt to come to a final decision between the crystalloid and colloidal theories of hardening by means of decisive experiments. On the one hand the earlier work, in which small amounts of cement were decomposed under the microscope by large excess of water, was undertaken with materials which to-day cannot be regarded as pure. On the other hand in researches on thin sections of set cement there are many possible sources of error which, if neglected, lead to erroneous results. For the purpose of the present investigation a comprehensive series of specimens was prepared and examined microscopically, and wherever possible chemically. These preparations included the three silicates $3CaO.SiO_2$, $2CaO.SiO_2$ and $CaO.SiO_2$, the two aluminates $3CaO.Al_2O_3$ and $CaO.Al_2O_3$, certain ordinary and high-strength Portland cements, and two aluminous cements. The binary compounds were prepared by intimately mixing chemically pure $CaCO_3$ and Al_2O_3 or SiO_2 in stoichiometric proportions for several hours, and then heating the mixture several times at a high temperature in the oxyhydrogen blowpipe as recommended by Dyckerhoff.[1] In the case of $2CaO.SiO_2$ the product fell to powder on cooling, but this was prevented by the addition of a trace of boric acid. The tricalcium aluminate was held at 1,350 deg. C. for several hours. If the temperature of formation is too high (if, for instance, melting point is reached) this aluminate decomposes into $5CaO.3Al_2O_3+CaO$. After prolonged heating the various products were again ground, heated, and annealed, and so on until no free lime could be detected with White's reagent.[2] The products were finally ground to the fineness of

[1] Dyckerhoff and Nacken, *Zement*, Nos. 1, 2 and 4, 1925.
[2] A. H. White, *J. Ind. Eng. Chem.*, No. 1, 1909.

cement in an agate mortar, and a few milligrammes were placed on a microscope slide with a drop or two of water ; this was then covered with a slip-glass which was carefully sealed around the edges with paraffin wax to prevent drying out. Photomicrographs were taken at intervals.

HYDRATION OF $3CaO.SiO_2$.—Microscopic examination of the hydration of $3CaO.SiO_2$ showed the formation of calcium hydroxide crystals and amorphous silica ; both appeared within twenty-four hours. Increased quantities of these two products were formed as hydration continued. The $Ca(OH)_2$ crystals were hexagonal tables and the amorphous material was gelatinous ; needles could not be found.

HYDRATION OF $2CaO.SiO_2$.—β-calcium orthosilicate is only slightly changed even after several weeks. A slight etching of the edges of certain grains can be seen. This agrees with the results of Klein and Phillips.

Fig. 1.—Alumina Sol.

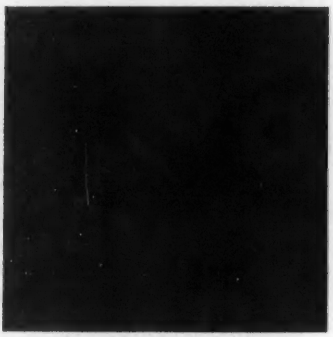

Fig. 2.—Spheroids of Hydrated Monocalcium Aluminate.

HYDRATION OF $CaO.SiO_2$.—Microscopic examination similarly shows no change in the metasilicate. No crystal formation can be detected.

HYDRATION OF $3CaO.Al_2O_3$.—When tricalcium aluminate is attacked by water fine needles and hexagonal plates are at once formed on the original grains. These crystals grow very rapidly ; they are at first extremely minute, but the rapidity of their growth is astonishing and the maximum size is reached in a few days.[3]

HYDRATION OF $CaO.Al_2O_3$.—The hydration of monocalcium aluminate began after a few minutes. A gelatinous amorphous mass was formed which enveloped the original grains and after the lapse of one day filled the whole field. At the same time spheroids developed radially from the grains. These consisted of hexagonal needle and plate crystals radiating from one central point. The needles appeared to be hexagonal plates turned edgewise and to be identical with the plates. Fig. 1 shows the amorphous gel mass and Fig. 2 a characteristic

[3] Eitel, *Zement*, No. 17, 1930.

radial spheroidal crystal. The preparation was tested with chemical stains. According to Keisermann[4] an alcoholic solution of anthrapurpurin stains free lime or lime compounds red. In the case of the specimen under discussion, the hexagonal plates, the needles, and the spheroids were thus stained red, but not the amorphous mass. The crystals may thus consist of calcium hydroxide or a calcium aluminate. A further test for free lime, i.e., $Ca(OH)_2$, by White's reagent gave a negative result. The crystals may thus be considered to be a calcium aluminate. This was further confirmed by the fact that patent blue stained both the amorphous mass and the crystals blue. This dye colours both free and combined alumina blue, and the amorphous gel is thus identified as $Al(OH)_3$.

Hydration of Portland and Aluminous Cements.—Various ordinary and high-strength Portland cements were investigated in the same way. In all cases the first small crystals appeared in 8 to 10 hours growing radially from the cement grains; these were extremely fine needles. In 24 hours the cement particles were totally surrounded by small needle crystals. In a further 24 hours

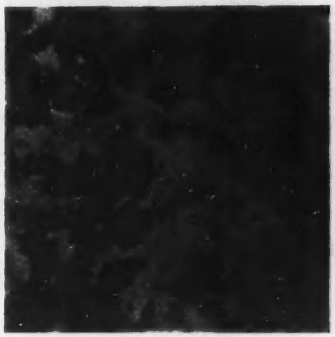

Fig. 3.—Portland Cement shortly after adding Water.

all the particles were densely hemmed in by these needles, which reached their maximum size in four to five days. After this time the first hexagonal crystals, of various sizes, were observed, together with amorphous gel. The hexagonal crystals, which according to Klein and Phillips consist of $Ca(OH)_2$ and calcium aluminate, became gradually larger and more numerous. The amorphous gel finally covered the whole slide in a fine thin layer. Figs. 3 and 4 show certain stages of the hydration, Fig. 3 showing a Portland cement shortly after the addition of water and Fig. 4 the same cement after ten days. In the latter the hexagonal tables, fine needles, and the gel between the cement grains are clearly visible.

In the same way the behaviour of aluminous cements in the presence of water was investigated under the microscope. The hydration of aluminous

[4] Keisermann, *Cement Eng. News*, No. 23, Vol. 10, 1911.

cement to all appearances follows in general the same course as that of Portland cement. After a day or two crystals and an amorphous gel are formed, the gel consisting in this case of colloidal alumina.

It would be very useful to know what happens during the hydration of a mixture of Portland and aluminous cements; this has long been an important technical problem. In 1924 W. Dyckerhoff[5] found that the two types of cement could not be mixed. Attempts have repeatedly been made to dilute the costly aluminous cement with the cheaper Portland, but they have all failed because the mixture instantly sets and attains no strength on hardening. An explanation of this phenomenon is afforded by the work of Lafuma[6] and P. Erculisse[7], which will be shortly described.

Lafuma found that two hydrated calcium aluminates were formed, viz., $4CaO.Al_2O_3.12H_2O$ and $2CaO.Al_2O_3.7H_2O$. On the hydration of the silicates he found no formation of hydrated tricalcium silicate—such as was described by Candlot[8] and Klein and Phillips[9] in setting cement. He obtained, on the other

Fig. 4.—Hydrated Portland Cement Clinker 10 days after adding water.

hand, only one compound, $CaO.SiO_2.2\frac{1}{2}H_2O$. In the presence of gypsum he discovered the two calcium sulphoaluminates in the set cement, viz., $3CaO.Al_2O_3.3CaSO_4$ and $9CaO.4SiO_2.Al_2O_3.7CaSO_4.80H_2O$. Lafuma further investigated the hydration of various cements in the presence of great excess of water, i.e., under conditions which do not hold in practice. With Portland cement the following hydration products were formed: $4CaO.Al_2O_3.12H_2O$, $2CaO.Al_2O_3.7H_2O$, $CaO.SiO_2.2\frac{1}{2}H_2O$, and $3CaO.Al_2O_3.3CaSO_4$. The following compounds were obtained with an aluminous cement: $2CaO.Al_2O_3.7H_2O$, $CaO.SiO_2.2\frac{1}{2}H_2O$, and free aluminium hydrate.

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[5] Dyckerhoff, *Zement*, No. 33, 1924.
[6] M. Lafuma, Thesis presented to the University of Paris (Veribert).
[7] P. Erculisse, Procès Verbaux 4th Meeting of the Belgian Assoc. for Testing Materials, Brussels, 1928.
[8] Candlot, *Bull. d'encouragement*, Vol. 89, p. 682, 1886; *Le Ciment*, Nos. 3, 4, 5, 1896.
[9] Klein and Phillips, *loc. cit.*

In the admirable work of Erculisse the setting of cement was studied by means of phase rule. Previous workers on the setting and hardening of cement have investigated the hydrolysis of the isolated individual constituents. According to Erculisse this is incorrect. The constituents of cement are for the most part insoluble or very slightly soluble anhydrous salts which are incapable of setting up an equilibrium with water. On mixing these anhydrous salts with water hydrolysis sets in and a more or less hydrated acid anhydride and base are always formed. Both these hydrated decomposition products—the acid anhydride and the base—react further with water and combine to form an insoluble hydrated salt. The reaction for the hydrolysis of a compound of formula A_mB_n (A=acid anhydride and B=basic oxide) proceeds according to this scheme in the following stages :

(1) $A_mB_n + \text{aqu.} = A_m \text{ aqu.} + B_n \text{ aqu.}$

(2) $A_m \text{ aqu.} + B_n \text{ aqu.} = A_m B_p \text{ aqu.} + (n - p)\ B \text{ aqu.} + \text{aqu.}$

(3) $A_m \text{ aqu.} + B_n \text{ aqu.} = A_p B_n \text{ aqu.} + (m - p)\ A \text{ aqu.} + \text{aqu.}$

For a complete understanding of the setting of cement the course of these fundamental reactions must be established. In the main reaction a very slightly soluble acidic anhydride is neutralised by a slighty soluble basic oxide, with the result that a hydrated salt is formed which is also only slightly soluble. Obviously the application of these ideas to the setting of cement is extremely difficult, since cement consists of numerous components of different chemical composition capable of reacting with one another.

Let us represent the acid anhydride by A, the basic oxide by B and the hydrated salt by AB aqu., when the reaction may be represented

$$A + B + n\,H_2O = A\,B.n \text{ aqu.}$$

According to the phase rule such a reaction is determined by the following factors : First, the system consists of the three components A, B and H_2O. Secondly, there are three variables, viz., pressure, temperature, and the composition of the liquid phase. The solid phases, each of which consists of a definite chemical compound, are not variables, and the vapour phase may be ignored. The system may thus be considered to consist of a maximum of four phases, viz., a liquid and three solid phases, and three components. Thus, according to Gibb's phase rule[10], there is one degree of freedom if all the phases are present. This, however, is not very probable since in most cases, if the pressure is defined, the composition of the liquid phase varies with the temperature. There are thus two degrees of freedom, and this is only possible if one of the four phases, e.g., A or B, has completely disappeared, i.e., if the reaction has proceeded to completion and resulted in one of the two systems

A, A B aqu., liquid phase.

B, A B aqu., liquid phase.

These conceptions can be applied to the study of the neutralisation of any number of insoluble acid anhydrides by a single base (lime in the case of cement),

[10] The phase rule states that a system will be in equilibrium when the number of degrees of freedom (F) is equal to the number of components (C) minus number of phases (P) plus 2; or $F = C - P + 2$.

or to the neutralisation of any number of bases by a single acidic anhydride. Since, as shown, the number of degrees of freedom is always two, in a system with $(n + 2)$ components only $(n + 2)$ phases can exist, i.e. $(n + 1)$ solid phases. With n acids and 1 base the maximum number of phases possible is $(2n + 2)$, viz., n acids, n salts, 1 base and the liquid phase, which proves that $(n + 1)$ solid phases must disappear. Thus the number of acids must always be in excess, and the neutralisation of the various acids must proceed simultaneously. The number and composition of the various salts that can be formed is determinable from such considerations.

If the setting and hardening of cement in the presence of water is considered on these lines it will be found analogous to the action of an almost insoluble salt on an almost insoluble acid anhydride, or of an acid salt on a basic salt. Regarding the setting of cement from the point of view of the phase rule, we have a system of x components with two degrees of freedom. Thus for equilibrium the number of phases must be equal to the number of components, and so long as there is a liquid phase the number of solid phases must be $(x - 1)$. Let us first consider the hydration of the two silicates present in Portland cement, viz., $3CaO.SiO_2$ and $2CaO.SiO_2$; the following equations of reaction are obtained:

(1) $3CaO.SiO_2 + \text{aqu.} = 2CaO.SiO_2\text{aqu.} + Ca(OH)_2$.

(2) $2CaO.SiO_2 + \text{aqu.} = CaO.SiO_2.2\frac{1}{2}H_2O + Ca(OH)_2$.

Both systems consist of three components, CaO, SiO_2 and H_2O. Therefore for equilibrium only two solid phases can exist together, and the hydrolysis must be complete.

It may be assumed that these two reactions proceed simultaneously, with the sole difference that (1) has a greater velocity of reaction than (2). It will be seen that the concentration of CaO in the liquid phase will be higher so long as $3CaO.SiO_2$ is still present. When equilibrium is attained $Ca(OH)_2$ concentration in the liquid phase is diminished; according to Lafuma it is 0.052 g. per litre.

Portland and aluminous cements differ in the nature of their silicates and aluminates as follows:

	Silicates.	*Aluminates.*
Portland cement	$3CaO.SiO_2$	$3CaO.Al_2O_3$
	$2CaO.SiO_2$	$5CaO.3Al_2O_3$
Aluminous cement	$2CaO.SiO_2$	$CaO.Al_2O_3$
		$5CaO.3Al_2O_3$
		or $2CaO.Al_2O_3.SiO_2$.

In the hydrolysis of both cements we are concerned with the action of aluminates on lime, since lime is formed on the hydrolysis of the silicates. If the two systems are studied from the point of view of velocity of reactions, the attainment of equilibrium on the completion of hydrolysis is governed on the one hand by the amount of lime available and on the other by the nature of the aluminates.

On these lines the behaviour of a mixture of Portland and aluminous cements can be elucidated. The first work on the problem was that of Dyckerhoff

(*loc. cit.*), who showed that mixing aluminous cement with Portland cement or lime led to very rapid setting. More recently the matter has been investigated by Kühl and Ideta[11] and Koyanagi.[12] The basis of the explanation is simply that the combination of monocalcium aluminate (the main constituent of aluminous cement) and lime to form dicalcium aluminate proceeds with much greater velocity than the conversion of tri- into tetra-calcium aluminate. It follows that in the presence of monocalcium aluminate the only silicate that can exist is the disilicate, since the concentration of lime in the liquid phase is much lower during the hydrolysis of dicalcium silicate than for tricalcium silicate, as stated. The scheme of reactions for Portland and aluminous cements is

(1) $3CaO.Al_2O_3 \rightarrow 4CaO.Al_2O_3$.
(2) $3CaO.SiO_2 \rightarrow 2CaO.SiO_2 + CaO \rightarrow CaO.SiO_2 + CaO$.
(3) $CaO.Al_2O_3 \rightarrow 2CaO.Al_2O_3$.
(4) $2CaO.SiO_2 \rightarrow CaO.SiO_2 + CaO$.

(1) and (2) apply to Portland cement and (3) and (4) to aluminous cement,

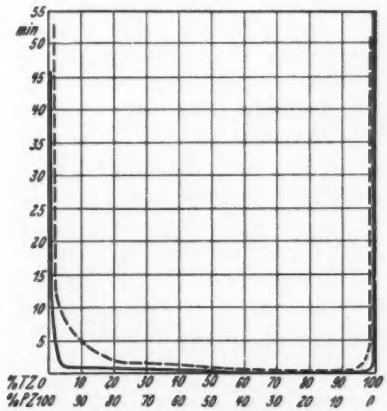


Fig. 5.—Initial Set (full curve) and Final Set (dotted curve) of Mixtures of Portland and Aluminous Cement.

ignoring the water. According to (2) the tricalcium silicate of Portland cement is decomposed to dicalcium silicate and CaO, and the dicalcium silicate to monocalcium silicate and CaO, while the CaO so freed serves for the gradual transformation of tricalcium aluminate into tetracalcium aluminate. According to (4) the dicalcium silicate of aluminous cement is decomposed into monocalcium silicate and CaO, and the CaO serves to convert the monocalcium aluminate into dicalcium aluminate in accordance with (3). In the case of a

[11] Kühl and Ideta, *Zement*, No. 34, 1930.
[12] Koyanagi, *J. Soc. Chem. Ind. Japan*, No. 33 and *Zement*, No. 37, 1930.

mixture of the two cements the reaction proceeds differently according to the following scheme :

$3CaO.Al_2O_3$.
$3CaO.SiO_2$ instantaneously—→$2CaO.SiO_2 + CaO$.
$CaO.Al_2O_3$ instantaneously—→$2CaO.Al_2O_3$.
$2CaO.SiO_2$ —→ $CaO.SiO_2 + CaO$.

In the top two lines we have the constituents of Portland cement, and in the bottom two lines those of aluminous cement ; in the mixture they all occur together. On adding water to the mixture vigorous hydrolysis of the tricalcium silicate at once occurs with formation of dicalcium silicate, since in the liquid phase monocalcium aluminate can only exist in contact with dicalcium silicate. This is proved by the fact that only this silicate occurs with monocalcium aluminate in fused aluminous cement. The lime set free from the tricalcium silicate is at once used for the conversion of mono- into di-calcium aluminate, and not for the conversion of tri- into tetra-calcium aluminate, since the velocity of the first reaction is incomparably greater than that of the second.

It would be interesting to investigate to what extent these considerations conform with practice, and the behaviour of Portland-aluminous cement mixtures during setting was therefore studied chemically and microscopically. For this purpose a series of mixtures of the two types of cement in various proportions was prepared. Each mixture was sieved through a fine sieve (180 meshes per inch) for several hours with the object of making them completely homogeneous. 300 g. of each mixture were gauged with 81 to 84 c.c. of water (27 to 28 per cent.) to give normal consistency. Pure aluminous cement required 28 per cent. of water for normal consistency, and pure Portland 27 per cent. The setting times were measured with the Vicat needle. For pure aluminous cement the initial set was three hours, and the final six hours ; for pure Portland the initial set was four hours, and the final eight hours. So small an addition as 1 per cent. of aluminous cement to the Portland lowered the initial set to 12 minutes 40 seconds and the final set to one hour. Fig. 5 shows graphically the initial (continuous curve) and the final setting time (dotted curve) of various Portland-aluminous cement mixtures.

Experiments with various Portland and aluminous cements gave in general the same results. Since the effect of either cement on the other is extremely pronounced even with small percentage additions, it appeared possible that it might be due to molecular solution, i.e., to extremely finely divided constituents. To test this hypothesis a small quantity of aluminous cement (15 g.) was shaken for several minutes with 81 c.c. of water and then rapidly filtered on the filter pump. (The filtrate was clear, but on long standing it became cloudy and a fine deposit of crystals separated on the sides of the flask.) Immediately after shaking the clear filtrate was mixed with 285 g. of Portland cement instead of mixing water. A proportion of 5 per cent. of aluminous cement to 95 per cent. of Portland was thus used, but the experiment differed from the earlier tests in that only the water-soluble constituents of the aluminous cement were added to the Port-

land, instead of the aluminous cement itself. The Portland cement again became quick setting, the results being initial set two minutes, final set eight minutes, as compared with an initial set of one minute forty seconds, and a final set of eight minutes when the aluminous cement was used. This experiment was repeated with a number of Portland and aluminous cements with the same general result.

The question of the composition of the water-soluble constituents of aluminous cement was then studied. Previous qualitative experiments had shown that when aluminous cement reacted with water metastable calcium aluminate solutions were formed. An attempt was made to determine the exact chemical composition of these calcium aluminates which are formed during the first stages of setting. For this purpose fifty parts of solid aluminous cement were shaken with one litre of distilled water for various long periods and the mixtures were then rapidly filtered on a filter pump. Samples of the filtrates were at once analysed; they were first slightly acidified with dilute HCl, after which the Al_2O_3 was precipitated as hydroxide and estimated as oxide by Blum's method.[13] The calcium was precipitated as oxalate and weighed as oxide. Other portions of the filtrates were set aside in well-stoppered flasks for further examination, and it was found that on standing part of the lime and alumina separated from the clear solutions. The metastable state passes slowly into a condition of equilibrium, which is attained in approximately two weeks. At the end of two weeks the filtrate was again filtered, and both filtrate and residue were analysed.

The percentage analysis of the aluminous cement investigated is: Insoluble residue, 0.23; loss on ignition, 1.20; SiO_2, 7.10; TiO_2, 2.16; Al_2O_3, 38.98; Fe_2O_3, 5.75; FeO, 1.26; CaO, 42.90; MgO, 0.25; SO_3, 0.17; total 100.00. Table I gives the analyses of the filtrates immediately on the conclusion of shaking, and the fourth column shows the molecular ratio CaO/Al_2O_3 of the dissolved oxides.

It is obvious from Table I that the amounts of lime and alumina dissolved in water rapidly increase during the first two hours. They then remain approxi-

TABLE I.

Time of shaking.	Grammes of dissolved Al_2O_3 per litre.	Grammes of dissolved CaO per litre.	Molecular ratio CaO/Al_2O_3.
15 minutes	1.04	0.58	1.016
30 ,,	1.38	0.70	1.00
60 ,,	1.54	0.85	0.99
2 hours	1.75	0.98	0.98
3 ,,	1.65	0.92	0.98
4 ,,	1.45	0.83	0.95
5 ,,	1.30	0.75	0.94
6 ,,	1.16	0.65	0.98
8 ,,	0.95	0.51	1.01
10 ,,	0.77	0.48	1.13
20 ,,	0.71	0.47	1.20
32 ,,	0.48	0.40	1.51
48 ,,	0.25	0.37	2.69

[13] W. Blum, Bureau of Standards Sci. Paper, No. 226.

mately constant for about an hour and then quickly fall. The molecular ratio of the dissolved CaO and Al_2O_3 remains constant for the first ten hours, having the value 1. Aften ten hours a greater quantity of the alumina and lime separates out and the solution above the cement becomes cloudy. The molecular ratio CaO/Al_2O_3 increases, and after 48 hours attains the value 2.69. The mechanism of the reaction in the solution is such that a metastable solution of lime and alumina in the ratio 1 : 1 is formed in the first period of the reaction, followed by the deposition of a large part of the alumina and lime, until finally a stationary condition is reached. Fig. 6 shows the solubility of alumina and lime plotted against time, and Fig. 7 shows the molecular ratio CaO/Al_2O_3 also plotted against time. Fig. 7 clearly shows that the aluminous cement filtrate consists of a meta-

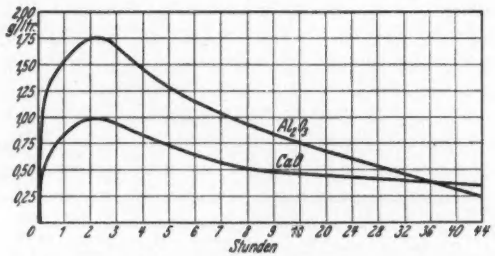


Fig. 6.—Solubility Curves of Aluminous Cement.

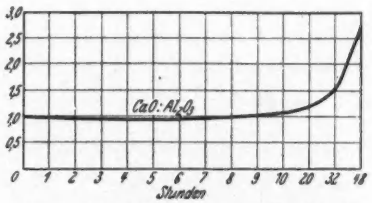


Fig. 7.—Molecular Ratio CaO/Al_2O_3.

stable solution of monocalcium aluminate for the first ten hours. These results satisfactorily agree with the investigation of L. S. Wells[14] on the action of water on the calcium aluminates. If mono- or tri-calcium aluminate or pentacalcium trialuminate is shaken up with water the results are very similar to those expressed in Table I and Figs. 6 and 7. The filtrates set aside for later examination were next investigated. Even an hour or two after filtration the filtrates became cloudy and a fine crystalline substance separated out and covered the bottom of the flask. In a few days small spherolithic crystals were formed on the sides of the flask, and later these were covered with a fine layer of amorphous material. Both crystals and amorphous substance were investigated chemically and microscopically.

[14] L. S. Wells, *Bureau of Standards J. Research*, Vol. 1, p. 951, 1928.

The crystals were flat hexagonal plates with the projection indices $\omega = 1.535 \pm 0.004$ and $\epsilon = 1.515 \pm 0.005$ found by Wells. The spheroliths consisted of aggregates of these crystals radiating from centres. The refractive indices agreed with those found by Wells and Klein and Phillips for hydrated tricalcium aluminate. The amorphous material was colloidal and without crystal form. Chemical tests by White's and Keisermann's methods showed that the crystals consisted of calcium aluminate and the amorphous material of hydrated alumina. Neither gave any reaction with White's solution, showing that there was no free lime present.

These experiments, as well as L. S. Wells' research, make the existence of aqueous monocalcium aluminate solutions very probable, and thus indicate with reasonable certainty that the accelerating action of aluminous cement on the setting of Portland cement is due to that compound. To still further confirm this result minute quantities of monocalcium aluminate were added to Portland cement, whereupon setting immediately took place on the addition of water.

(*To be continued.*)

Notes from Abroad.

Hungarian Cement Production.

The total production of Portland cement in Hungary for the year 1931 is reported to be 13 per cent. less than in 1930 and 34 per cent. less than in 1929.

Cement Production in Italy.

The production of Portland cement in Italy for the period January to June 1932 totalled 1,423,505 metric tons, compared with 1,472,137 tons and 1,676,833 tons for the first half of 1931 and 1930 respectively. For the month of June the production was 330,103 metric tons in 1932, 297,343 tons in 1931, and 321,288 tons in 1930.

Japanese Cement Production.

On July 7 a meeting of the Cement Rengokai increased the cement production curtailment rate by 2.5 per cent. until the end of August, making the total restriction 56 per cent.

Cement Sales in Poland.

For the period January to July 1932 the sales of Portland cement in Poland amounted to 224,000 tons, compared with 329,100 tons and 362,100 tons in 1931 and 1930 respectively. The sales for the month of July were 50,900 tons, against 79,200 tons and 98,900 tons for the same months in 1931 and 1930.

A Czechoslovakian Cement Company.

A.Z. für Zement und Zementwaren, of Prague, reports a net profit of Cr. 34,733 (£211) for the year 1931, against Cr. 4,353 (£26) for the preceding year. The reconstruction of the company's works at Mariaschein and Olmutz is now completed.

The New Works of the Green Island Cement Co., Ltd., Hong-Kong.—II.

By HENRY POOLEY, Junr., B.Sc., Assoc.M.Inst.C.E., A.M.I.Mech.E.
CONSULTING ENGINEER FOR THE PLANT.
MAIN CONTRACTORS: VICKERS-ARMSTRONGS, LTD.

Raw Mill Section.

The limestone from the crushing plant is deposited by the conveyor into one of the three reinforced concrete bunkers. Incorporated with the limestone bunkers are the sand or iron-ore bunkers. Under each limestone bunker is a 54-in. diameter feed table for feeding the crushed limestone to each of the raw mills, and under each sand or ore bunker there is a 36-in. diameter feed table. A pipe from the clay-feed tank feeds clay slurry to the mills, and on each outlet provision has been made for fitting a series of nozzles to the clay-feed pipe;

One of the Raw Mills, with Limestone Bunker Above and Slurry Pump House to the Left.

these nozzles are from $\frac{5}{8}$-in. diameter downwards in sixteenths, and there are four or five nozzles for each pipe. By this means the clay valve can be left fully open and the feed of clay adjusted by nozzles; it is an easier matter to keep the feed of clay slurry regulated in this way than to depend upon the opening of a valve, especially with native labour and at night. A 3-in. pipe with controlling valve leads water to the mill inlet. The feed tables and water valves are fitted with indicators to enable an easy and constant regulation of the mix.

There are three raw mills each 40 ft. long by 6 ft. 6 in. diameter. The mills are divided into three compartments, the first chamber being lined with cast-steel plates and provided normally with a charge of three tons of 5-in. 0.8 carbon steel balls and three tons of 4-in. steel balls. The first chamber is 7 ft. 1¼ in. in length and the weight of steel balls is therefore 0.85 tons per foot run. The second chamber is lined with cast-steel plain plates and contains 3½ tons of 3-in. steel balls and 3½ tons of 2-in. steel balls. The second chamber is 9 ft. 1½ in. long, and therefore contains 0.77 tons of grinding media per foot run. The third chamber is lined with silex blocks and contains 8½ tons of 1-in. cast-iron cylpebs and 8½ tons of ¾-in. cast-iron cylpebs. The length of the third chamber is 22 ft. 6 in., and therefore the weight of grinding media per foot run is 0.75 tons. The intermediate and end diaphragm plates are of cast steel. That at the outlet is formed of renewable plates having tapered slots near the periphery through which the material is discharged by lifters through the outlet trunnion. The mill is supported in self-aligning cast-steel, water-cooled, greased trunnion bearings supported on cast-iron bedplates. The stepped lining plates vary in thickness from ⅞ in. to 3½ in., and are provided with countersunk cored holes for 1¼-in. bolts. The intermediate cast-steel lining plates are 1¼ in. thick. The gearing consists of toughened cast steel of 30 to 35 tons tensile strength. The spur ring has machine-cut teeth with 3½-in. pitch at 17 in. face, and is made in halves with machined joints and bolted together. The pinion is of toughened cast steel of similar strength, machine cut, having teeth 3½-in. pitch and 18-in. face, and is 9½-in. diameter bore, keyed to the countershaft. The gearing is totally enclosed. The speed of the mill countershaft is 132 R.P.M. The mill is operated through reduction gearing by a 475-B.H.P. synchronous induction motor operating on 2,200 volts with a speed of 720 R.P.M. The enclosed reduction gear is of the single-reduction type with a nominal rating of 500 H.P. and a maximum rating of 1,000 H.P. The speed reduction is from 720 R.P.M. to 127/59 R.P.M. On the low-speed shaft there is a flexible coupling, and on the shaft between the motor and the gear box a Bibby flexible coupling. The speed of the mill is 25 R.P.M. The guaranteed output of the mill is thirteen tons of dry raw meal per hour when grinding slurry to 5 per cent. residue on the 180 by 180-mesh sieve.

The mills are driven at the feed end, and the motor house is formed below the underside of the concrete limestone bunkers and is completely shut off from the mill house by a brick wall with three doors.

The slurry pumps are in the mill house and are of the same type as those described for clay slurry, except that they are furnished with cast-iron plungers. They are three in number and are interchangeable, one being used for pumping slurry from the mills to the correcting tanks, another for pumping from the tanks to the kiln feed tank, and a third acting as a stand-by. In the slurry pump house a fourth 8-in. 3-throw pump, similar to those used for clay and slurry pumping, is installed to pump clay slurry from the large clay storage tank to the small clay feed tank on top of it when the wash-mills are not operating. An endeavour

was made to do without the fourth 8-in. pump by returning clay slurry by gravity through the pipe from the bottom of the main clay tank to the sump in the wash-mill. It was not possible to arrange an open launder. In this way clay slurry from both the wash-mill and the main clay tank was pumped by one of the clay pumps in the wash-mill. However, the sand and grit contained in the washed clay slurry soon silted up the return pipe and the fourth pump had to be installed. The pump used for pumping slurry to the kilns, instead of drawing directly from a tank, sucks the slurry from a sump filled from whichever tank or tanks are being used for this purpose. This sump is situated in the slurry pump house and to it gravitates the overflow slurry from the kiln-feed tank. In order to keep a constant head of slurry in the kiln-feed tank rather more slurry than

Approach to Works: the Crusher House is to the Left, and the Clinker Store to the Right.

is required for the kilns is pumped to it, and the overflow is returned to the sump. By this arrangement it is possible to determine the quantity of slurry being manufactured and the quantity being pumped to the kiln.

Slurry Mixing Section.

For the purpose of correcting and storing the slurry six reinforced concrete tanks are provided, each 34 ft. high and 21 ft. 6 in. in diameter. These tanks are raised 6 ft. 6 in. from the ground level and are flat bottomed with a slight slope towards the outlet. Cast-iron slurry piping 6 in. in diameter with the necessary valves is arranged to lead the slurry direct to the sump in the slurry pump-house, from where it is pumped to the kilns. The sump contains about 770 cub. ft. of slurry. An overflow is arranged to operate at about 18 in. from the

top, leading from this sump to the mill discharge sump. The overflow from the kiln-feed tanks is returned to this sump. The piping is so arranged that one or more tanks can feed slurry to this sump at speeds regulated by their respective valves.

Slurry piping 6 in. in diameter is also arranged to discharge the slurry as it comes from the pump, drawing it from the mill discharge sump. It will be noted that this arrangement allows a determination of the amount of slurry being ground by the mills. Each tank is provided with an internal ladder with rungs 1 ft. apart, and at every 5 ft. on the ladders there is a distinguishing mark to enable a quick determination of the height of slurry in the tank. In this case a difference in level of 1 ft. in the slurry tanks represents 364 cub. ft., or approximately 16.7 tons of slurry containing 36 per cent. of water, corresponding to about 10.7 tons of dry raw material. As slurry is pumped direct from the mills to one tank it is an easy matter to estimate the quantity manufactured over a given period by watching the height of the slurry in the tanks. In a similar manner, as the slurry discharges from the tanks to a sump and as the overflow of slurry pumped from this sump to the kilns returns to the same sump, it is a simple matter by watching the depth to which the slurry falls to estimate the quantity of slurry being transferred to the kilns. For correction purposes the chemist analyses at frequent intervals the slurry in the tank which is being filled, and by determining which ingredient is deficient in the mix the necessary adjustment can be made at the mill feed.

A seventh tank is provided for clay slurry storage. This is kept in constant agitation, compressed air being introduced through six ¾-in. air pipes supplied by a 1¼-in. main. On the top of the clay tank a smaller reinforced concrete clay tank, 6 ft. diameter by 7 ft. high, is situated. Clay slurry is pumped directly from the wash-mills to this small feed-tank and the overflow falls into the main clay-storage tank. A pipe connects the clay-feed tank to the raw mills, controlled by valves and the nozzles referred to previously. In the event of the wash-mill not working, which occurs at any rate once during twenty-four hours, an 8-in. 3-throw plunger pump similar to that used for clay and slurry service can pump clay slurry from the main clay-storage tank to the small clay-feed tank, from whence it is fed to the mills. From the small clay-feed tank a 3-in. pipe provided with the necessary valves can lead clay slurry direct to any of the six slurry tanks, thus enabling the chemist to have an additional control over the mix.

On top of one of the slurry tanks is a concrete feed-water tank which provides water for cooling purposes and for the process. It is possible to manufacture clinker without any trouble in the kilns when using up to about 50 per cent. of sea water with the slurry.

The slurry is agitated by compressed air, produced by two double-acting single-stage vertical compressors direct-coupled through gearing to 75-B.H.P. motors running at 485 R.P.M. Each compressor is capable of delivering 450 cub. ft. of free air per minute at a working pressure of 50 lb. per square

inch. Normally the pressure registered at the automatic 12-way valve is 40 lb. per square inch. The air is led to a patent 12-way valve at the top of the slurry tanks. The compressed air, acting on a piston and throwing it one way or the other, operates a ratchet which controls a supply of air through twelve 2½-in. gas mains, two for each tank; from these mains twenty-one ¾-in. pipes pass down into each slurry tank, where they are held rigidly at the bottom, half way up the tank, and at the top. The operation of the valve is to control the supply of compressed air for agitating the slurry. First, half of one tank is agitated for a period of about four minutes, and after an interval the supply switches over to

The 254-ft. "Reflex" Kilns, showing Cooling Cylinders at Discharge End.

the next half-tank for a similar period. The cycle of all six slurry tanks is completed in one hour, and each tank receives two agitations during that period. In the event of one tank being empty the air mains to this tank are shut off by a valve. The 12-way valve controls the agitation of the slurry in the six tanks entirely automatically and is operated by a ¼-H.P. motor running at 1,400 R.P.M. The air agitation of the clay-slurry tank is controlled by hand.

Kiln and Coal Section.

Slurry from the sump in the slurry pump house is pumped directly to the kiln-feed tanks on top of the kiln flue. There is one tank per kiln, each 5 ft.

long by 4 ft. wide by 2 ft. 9 in. deep. The slurry feed is at one end of the tank. At a distance of 3 ft. 9 in. from the slurry-feed end there is a notched division plate in the tank, and between the slurry feed and the division plate there is a baffle arrangement consisting of a wide mesh netting which ensures that the head of slurry flowing over the notch is unaffected by the pulsations of slurry through the feed pipe, and stops extraneous matter which might clog the notch. The outlet of slurry is at the opposite end of the tank. An overflow of slurry is arranged between the baffle screen and the feed end of the tank, which gravitates to a flume, and the overflow is led back to the sump in the slurry pump house. The slurry from the feed tank gravitates to a measuring pot with a capacity of 3 cub. ft. of slurry, or approximately 305 lb. The pot is fitted with a plug, and when the stream of slurry fills it in 30 seconds the feed is correct for a kiln output of 6 tons per hour. The measuring pot has an overflow pipe which comes into use if the plug is left in position too long. The slurry next falls through a pipe to a conical hopper bolted directly on to the 9-in. kiln-feed pipe. The discharge from the flue-dust hopper is arranged to fall so that the stream of slurry impinges upon the falling dust and both are introduced in this way into the kiln through the feed pipe.

There are two kilns, each 240 ft. long plus the length of the recuperator; the overall length, including the recuperator, is 254 ft. The upper portion of the kiln, comprising about 150 ft., is 7 ft. 9 in. in diameter. There is a decarbonating zone of 11 ft. diameter, and this section, including the taper portion, is about 45 ft. long. The remainder of the kiln, consisting of the firing and cooling zones, is 9 ft. in diameter.

The kiln is carried on five tyres, and the kiln body is constructed of $\frac{5}{8}$-in. and $\frac{3}{4}$-in. boiler quality acid-steel plates. The body is reinforced under each tyre with two mild-steel wrapper plates $\frac{3}{4}$-in. and $\frac{5}{8}$-in. thick. Under the gearing the shell is reinforced by one wrapper plate $\frac{5}{8}$-in. thick riveted around the exterior of the shell. The driving gear comprises a cast-steel machine-cut spur ring of toughened cast steel of 30 to 35 tons tensile strength. The ring is in halves, attached to the shell by heavy steel tangential plates. The reduction gears are machine-cut cast steel of similar strength, mounted on forged steel shafts, running in grease-lubricated gun-metal step bearings mounted on cast-iron bedplates. At the end of the second motion shaft a flexible coupling is keyed for direct attachment to the totally-enclosed reduction-gear box. The reduction gear and motor are mounted on the same cast-iron bedplate. The motor is 60 B.H.P. of variable speed from 360 to 720 R.P.M. The starting torque of these motors is 200 H.P. The gear box reduction is 720 R.P.M. Between the motor and the gear box is a Bibby coupling. The speed of the second motion shaft of the kiln gear is from 10 to 20 R.P.M. By means of the variable speed motor the speeds of the kiln can be varied from one revolution in 48 seconds to one revolution in 25 seconds. In all there are eight different speeds.

Four of the tyres are 11 in. wide, while the fifth, at the bottom end, is 20 in. wide, of the floating type made of 40 to 45 tons tensile strength cast steel. They

are supported on cast-steel rollers 39 in. and 38 in. diameter, shrunk on forged steel shafts and turning in large water-cooled cast-iron grease-lubricated bearings 9 in. by 15 in. and 11 in. by 19 in. respectively. Air seals are provided at the upper end of the kiln to ensure non-leakage of air past the revolving kiln into the flue. The seals are of the floating type, and are also provided at the end of the recuperator. For a distance of 70 ft. from the top end of the kiln, chains are suspended to afford additional drying area for the incoming slurry.

From the feed end of the kiln for a distance of 144 ft. the lining consists of 4 in. of ordinary quality high-silica firebrick. The next 20 ft. is furnished with a 5-in. lining of second-quality high-alumina refractory blocks. The next 38 ft., which comprises the enlarged decarbonating zone, with the exception of the taper section at the lower end, is furnished with a 6-in. lining of second-quality high-alumina blocks. The lower taper of this enlarged zone, comprising a length of 7 ft., the firing zone, and the 9-ft. diameter section of the kiln (a total of 37 ft.) are provided with 6-in. first-quality aluminous lining blocks. Finally, the end taper section of the kiln and a short straight piece, comprising 8 ft. altogether, have a 6-in. aluminous lining of second quality. At the lower end of the firing zone there is a nose ring of firebrick to act as a dam to retain the outgoing clinker a little longer in the kiln. The blocks are carefully laid, using only a thin wash of cement and water.

The main body of the recuperator is 9 ft. in diameter and 14 ft. long, constructed of $\frac{3}{4}$-in. and $\frac{5}{8}$-in. mild steel plates having machined joints tapering to 8 ft. diameter at the discharge end. Equally pitched around the circumference of this cooler is a set of twelve mild steel cylinders 3 ft. 6 in. in diameter by approximately 14 ft. long, built up of $\frac{1}{4}$-in. steel plates and fitted with spiral steel lifters in interchangeable sections. The clinker falls through ten outlets at the bottom end of the cooler, at which points cast steel chutes lined with heat-resisting renewable liners are riveted to the shell, and through these chutes it passes into the previously-mentioned cooling cylinders. The spiral lifters in the cylinders cascade the clinker in the opposite direction, and it finally leaves the cooler at the end of the cylinders, falling into a chute and thence to either of the shaker conveyors underneath. Inside the main body of the recuperator there are ten heat-resisting cast-iron nose rings and grids over the chutes discharging into the outer cylinders.

The guaranteed output of each kiln was 1,000 tons of clinker per week and the coal consumption 23 per cent. of dried coal per ton of clinker produced, the coal to be " standard " coal containing 12,600 B.T.Us. per lb. ground to a fineness of 10 per cent. residue on the 180-mesh sieve. The slurry moisture content was not to exceed 36 per cent. with 1.53 tons of dry raw materials to 1 ton of clinker, and the temperature of the slurry was not to be less than 60 deg. Fahr. The performance of the kilns under test was rather better than this, as may be seen from the test sheets later.

Powdered coal is injected into the kiln by high-pressure fans, which have water-cooled bearings, renewable wearing plates, and an adjustable cold-air

inlet, and which are direct-coupled to a variable-speed motor. The speed of the fan motor is from 720 R.P.M. to 1,450 R.P.M., and the horse power is 35 B.H.P.

The mixed coal in the reinforced concrete storage bunkers is extracted for grinding purposes by means of two 48-in. diameter feed tables of similar construction to those already described. The coal is then passed through a rotating star feeder, which acts as a check on air being blown out in this direction, and then falls into the coal mills, of which two are provided. Hot air drawn from the cooler is also introduced into the feed end of the mill.

The mill is of the air-swept ball-mill type and has two compartments. Each mill is 7 ft. 3 in. diameter by 7 ft. 10 in. long. The preliminary grinding chamber is lined with special cast-steel step plates, and the finishing chamber with hard cast-iron plates. The mill countershaft speed is 126 R.P.M., while the motor speed is 750 R.P.M. The motor is 150 B.H.P. and the mill is driven from the motor by means of suitable reduction gearing in a similar manner to the raw mill. In the primary compartment a charge consists of 36 cwt. of 3-in. balls and 18 cwt. of 2-in. 0.8 carbon-steel balls. In the finishing compartment are three tons of 1-in. hard cast-iron cylpebs and three tons of ¾-in. cylpebs. When the coal is fine enough the draught draws it up a pipe leading to a cyclone separator. In this cyclone the powdered coal falls to the bottom and thence to the boot of an elevator, after passing through a second star feeder, which again acts as an air seal. The air is drawn from the top of the cyclone and thence to the coal-firing fan. The two elevators are of the vertical chain-bucket type, 16 in. wide and of similar construction to that described for crushed limestone. They are driven through gearing by 5-H.P. motors at 750 R.P.M. These elevators discharge the coal into two mild-steel powdered-coal hoppers, each containing about ten tons of powdered coal. Underneath each hopper is a double-worm extractor, 6 in. diameter, with enclosed drive and directly coupled through gearing of variable-speed 5-H.P. motors running at 360 to 720 R.P.M. Coal-agitating gear is provided in the coal-feed hoppers to prevent the coal arching and possibly causing flooding. Each agitating gear is driven by a 3-B.H.P. motor at 715 R.P.M., operating a vertical shaft with paddles inside the hopper. The hot-air piping in the air-swept coal plant is lagged, and the pipe is arranged with valves so that each coal mill can run in conjunction with the other. One coal mill is guaranteed to provide sufficient coal for two kilns.

(To be continued.)

[Note:—Manufacturers' announcements regarding the plant at Green Island Cement Works are given in a Special Supplement in this number.]

Proposed New Indian Cement Works.

It is reported that an Indian cement manufacturing concern proposes to build a new plant in the Coimbatore district (Madras Presidency) on a site near Madukari railway station, with an output of 60,000 tons a year.

A Graphic Method for Determining the Constituents of Portland Cement from the Chemical Analysis.

By O. F. HONUS

In CEMENT AND CEMENT MANUFACTURE for 1931, p. 992, I described a method for determining the rational composition of Portland cement based upon the molecular weights and molecular quantities of the individual compounds. It may be remarked that before my paper appeared a similar, though not identical, method was put forward by W. C. Hansen of the Bureau of Standards, U.S.A., whose paper incited me to undertake my own work. Since this method has proved valuable as a criterion of the quality of Portland cements it has now been extended and developed into a graphical method of determining the constituents of cement from the chemical analysis.

Before describing this method in detail it should be stated that it is convenient in determining the contents of calcium oxide, and of those of its compounds present in cement in quantities up to 3 per cent., to work with values multiplied by twenty, and for the components present in quantities from four to 10 per cent. to multiply the numerical values by ten. This minimises the errors which are readily made in using a graphical method with small numbers.

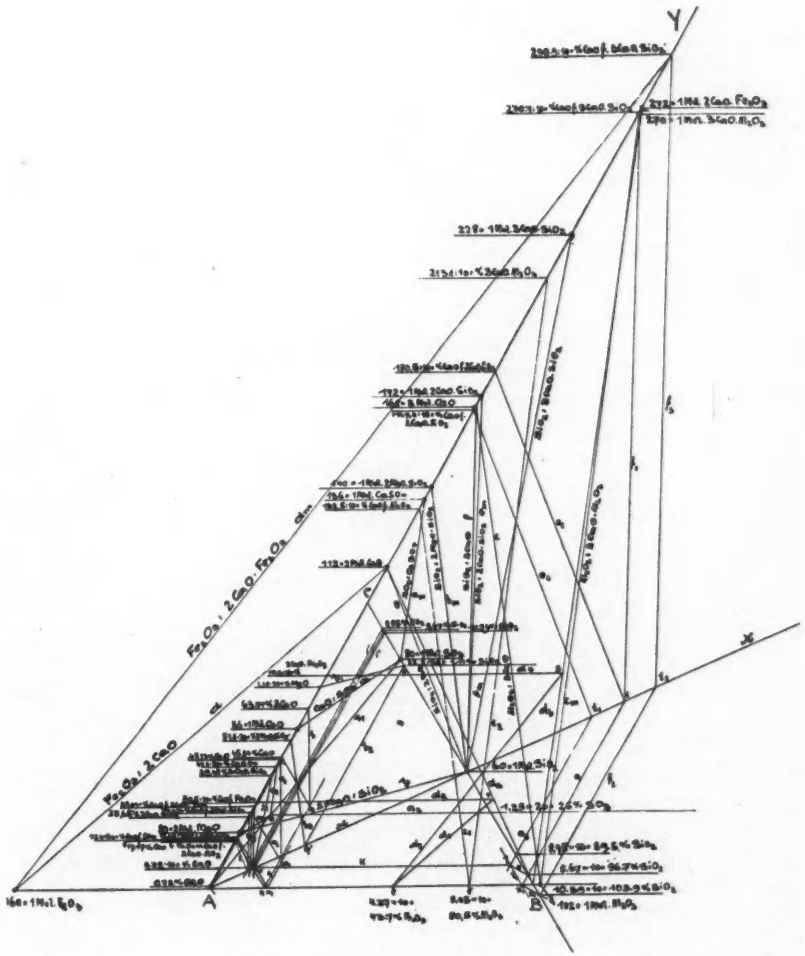
All molecular combinations which enter into the structure of cement must first be plotted in the diagram. An equilateral triangle of 10 cm. side* is constructed, and the side AC continued to Y. Along ACY, with A as zero, 5.6 cm., 11.2 cm., and 16.8 cm. are marked off, corresponding respectively to 56, 112 and 168 parts CaO, or 1, 2 and 3 Mols. All the compounds to be dealt with must also be inserted on this side of the triangle, and the following points are therefore marked: 13.6 cm. = 1 Mol. (136 parts) $CaSO_4$; 14.0 cm. = 1 Mol. 2 $MgO.SiO_2$; 17.2 cm. = 1 Mol. 2 $CaO.SiO_2$; 22.8 cm. = 1 Mol. $3CaO.SiO_2$; 27.0 cm. = 1 Mol. $3CaO.Al_2O_3$; 27.2 cm. = 1 Mol. $2CaO.Fe_2O_3$. MgO is plotted along CA with C as zero; 8.0 cm. = 2 Mols. MgO. Along AB 10.2 cm. = 102 parts (1 Mol.) Al_2O_3, and along BA 16.0 cm. = 1 Mol. Fe_2O_3. SiO_2 is plotted along CB, and 6.0 cm. = 1 Mol. SiO_2. SO_3 is plotted along BC and 8.0 cm. = 1 Mol. SO_3. We thus obtain the following percentage values represented by the three apices of the triangle:

$$A = 0CaO = 100MgO = 100\ Fe_2O_3 = 0Al_2O_3.$$
$$B = 0Fe_2O_3 = 100SiO_2 = 100Al_2O_3 = 0SO_3.$$
$$C = 0SiO_2 = 100CaO = 100SO_3 = 0MgO.$$

The proportional compositions represented by various straight lines in the figure will now be defined.

(1) The direction of the straight line *a* joining 56 parts CaO to 80 parts SO_3 represents the molecular ratio CaO : SO_3.

* The diagram in the text is reduced to half this scale.



[This diagram is half full size.]

(2) The straight line a_m joining $80SO_3$ to 136 $CaSO_4$ represents the ratio $SO_3 : CaSO_4$.

(3) Line b joining 80 MgO and 60 SiO_2 represents $2MgO : SiO_2$.

(4) Line b_m joining 60 SiO_2 and 140 $2MgO.SiO_2$ represents $SiO_2 : 2MgO.SiO_2$.

(5) Line c joining 102 Al_2O_3 and 168 CaO represents $Al_2O_3 : 3CaO$.

(6) Line c_m joining $102Al_2O_3$ and 270 $3CaO.Al_2O_3$ represents $Al_2O_3 : 3CaO.Al_2O_3$.

(7) Line d joining $160Fe_2O_3$ and 112CaO represents $Fe_2O_3 : 2CaO$.

(8) Line d_m joining $160Fe_2O_3$ and 272 $2CaO.Fe_2O_3$ represents $Fe_2O_3 : 2CaO.Fe_2O_3$.

(9) The auxiliary line d_a is drawn between B (the Fe_2O_3 origin) and 112 CaO.

(10) The auxiliary line d_b is drawn between B and 272 $2CaO.Fe_2O_3$.

(11) Line e joining $60SiO_2$ and 112CaO represents $SiO_2 : 2CaO$.

(12) Line e_m joining $60SiO_2$ and 172 $2CaO.SiO_2$ represents $SiO_2 : 2CaO.SiO_2$.

(13) Line f joining $60SiO_2$ and 168CaO represents $SiO_2 : 3CaO$.

(14) The line f_m joining $60SiO_2$ and 228 $3CaO.SiO_2$ represents $SiO_2 : 3CaO.SiO_2$.

These lines provide all the necessary bases to enable us to find with relative ease the required CaO and SiO_2 contents, and the contents of the compounds containing Al_2O_3 and Fe_2O_3.

Application of the Method.

Consider a cement of percentage composition 63.01CaO, 20.45 SiO_2, 8.05 Al_2O_3, 4.37 Fe_2O_3, 1.48 MgO, 1.25 SO_3. It is required to determine the compounds of which this is composed.

(*a*) DETERMINATION OF THE AMOUNT OF CaO COMBINED WITH SO_3 AND THE $CaSO_4$ CONTENT.—The point A is joined to 80 SO_3 by line a_1. Through the point $1.25 \times 20 = 25SO_3$, a line a_2 is drawn parallel to BA, and intersects a_1 at point o. From o are drawn two lines : the first, a_3, parallel to a meets AC at the point 17.4, and $17.4/20 = 0.87$ per cent. CaO ; the second line from o, a_4, is drawn parallel to a_m, meeting AC at the point 42.4, and $42.4/20 = 2.12$ per cent. $CaSO_4$.

(*b*) DETERMINATION OF THE AMOUNT OF SiO_2 COMBINED WITH MgO and of the $2MgO.SiO_2$ CONTENT.—A parallel to b is drawn through the point $1.48 \times 20 = 29.6$ per cent. MgO ; this line, b_1 meets the SiO_2 axis CB at $p = 22.2/20 = 1.11$ per cent. SiO_2. Through p is drawn a line b_2, parallel to AC, which meets line Ax at q. Through q is drawn a parallel b_3 to b_m, meeting AC at $51.8/20 = 2.59$ per cent. $2MgO.SiO_2$.

(*c*) DETERMINATION OF THE AMOUNT OF CaO COMBINED WITH Al_2O_3 AND THE TRICALCIUM ALUMINATE CONTENT.—c_1 is drawn parallel to c through point $8.05 \times 10 = 80.5$ per cent. Al_2O_3, and meets ACY at $132.5/10 = 13.25$ per cent. CaO. c_2 is drawn parallel to c_m through 80.5 Al_2O_3, meeting ACY at $213.1/10 = 21.31$ per cent. $3CaO.Al_2O_3$.

(*d*) AMOUNT OF CaO COMBINED WITH Fe_2O_3 AND DICALCIUM FERRITE CONTENT. —d_1 is drawn parallel to d through point $4.37 \times 10 = 43.7$ per cent. Fe_2O_3,

meeting d_a in r; d_3 is drawn through r parallel to BA, meeting AC at 30.5/10 = 3.05 per cent. CaO. A parallel d_2 to d_m through 43.7 Fe_2O_3 meets d_b in s; d_4 is drawn through s parallel to BA, cutting AC at 74.3/10 = 7.43 per cent. $2CaO.Fe_2O_3$.

(*e*) Amounts of CaO and SiO_2 combined as di-and tri-calcium silicates, and percentages of these two compounds in the cement.—The analysis of the cement gave 63.01 per cent. CaO. Of this the following percentages have been accounted for: 0.87 for SO_3, 13.25 for Al_2O_3, and 3.05 for Fe_2O_3, total 17.17. There is therefore still available for silicate formation 63.01—17.17 = 45.84 per cent. CaO.

The total SiO_2 is 20.45 per cent., of which 1.11 per cent. has been accounted for in the $2MgO.SiO_2$, leaving 19.34 per cent.

If desired these additions and subtractions may be carried out graphically, but we shall only show the CaO subtraction as an example. From the point 17.17 on AC is drawn a parallel v to CB, which cuts AB in v_1. A parallel v_2 to AC is drawn through v_1, and a perpendicular v_3 to AB through 63.01 CaO, the two meeting in v_4. A parallel to BC is drawn through v_4 which meets AC at 45.84 per cent. CaO.

It is convenient to divide the available SiO_2 into two equal parts for the purpose of calculation, giving 19.34/2 = 9.67 per cent. SiO_2 for di- and tri-calcium silicate respectively.

A parallel e_1 to AC is drawn through the point 9.67 × 10 = 96.7 per cent. SiO_2, and meets the line x in t; e_2 is drawn through t parallel to e, meeting ACY at 180.5/10 = 18.05 per cent. CaO for $2CaO.SiO_2$. A parallel f_1 to f is also drawn through t, meeting ACY in 270.7/10 = 27.07 CaO for $3CaO.SiO_2$. The sum of these is 18.05 + 27.07 = 45.12 per cent. CaO. This addition may be carried out graphically as follows: From point 18.05 on AC a parallel w to CB is drawn, cutting AB in w_1; through w_1 is drawn a parallel to AC; through 27.07 CaO is drawn a parallel w_2 to w, cutting the parallel to AC through w_1 in point w_2; a perpendicular to AB is drawn through w_3 and cuts AC at the point 45.12 per cent. CaO.

According to our calculations 45.84 per cent. CaO is available for silicate formation, and we must therefore account for the difference 45.84—45.12 = 0.72 per cent. This is combined as tricalcium silicate, and we must accordingly subtract 0.72 per cent. from the silica allotted to the di-silicate and add it to that for the tri-silicate. In cases where the CaO difference is a negative quantity the reverse process must be carried out, and the appropriate value must be subtracted from the SiO_2 allotted to the tri-compound and added to that for the di-silicate. In the present case we obtain 9.67—0.72 per cent. SiO_2 for the di-silicate and 9.67 + 0.72 per cent. SiO_2 for the tri-silicate.

The CaO difference is found graphically as follows: From point 45.84 CaO on AC a parallel to BC is drawn, and similarly a parallel to AB is drawn through 45.12 CaO; through the point of intersection of these two is drawn a parallel to CA, cutting AB in a point from which a parallel to BC is drawn; this last line

cuts AC at 0.72 per cent. CaO. The addition and subtraction of the CaO difference from the SiO_2 is carried out graphically by multiplying the figures by 10. From the point $0.72 \times 10 = 7.2$ per cent. CaO a parallel k is drawn to AB. Line e_1 cuts AB at n_1, from which point is drawn a parallel l_1 to BC cutting k in l. From l the line e_3 is drawn parallel to e_1; this cuts BC at $89.5/10 = 8.95$ SiO_2 and meets Ax at t_1. The parallel e_4 to e through t_1 meets ACY at $167.06/10 = 16.70$ per cent. CaO combined as $2CaO.SiO_2$. The point l is joined to the point 96.7 SiO_2 by the line g, and the parallel g_1 to g through n_1 cuts CB at $103.9/10 = 10.39$ SiO_2; f_2 is drawn through this last point parallel to e_1 and meets Ax in t_2; f_3 is drawn through t_2 parallel to f and meets ACY at $290.9/10 = 29.09$ per cent. CaO combined as $3CaO.SiO_2$.

The above construction can also be carried out in the un-multiplied natural figures. In this case the points of intersection of Ax are $i'' = t_1$, $i' = t$ and $i''' = t_2$. The parallel h to e through i'' meets AC at 16.7 per cent. CaO (for $2CaO.SiO_2$); h_1 parallel to e_m meets AC at 25.65 per cent. $2CaO.SiO_2$; j, parallel to f through i''', meets AC at 29.09 per cent. CaO; and j_1, parallel to f_m through i''' meets AC at 39.48 per cent. $3CaO.SiO_2$.

The results obtained by this graphical method are summarised in the table below:

Percentage analysis.	$CaSO_4$	$2MgO.SiO_2$	$2CaO.Fe_2O_3$	$3CaO.SiO_2$	$3CaO.Al_2O_3$	$2CaO.SiO_2$
63.01 CaO	0.87	—	3.06	29.09	13.26	16.70
20.45 SiO_2	—	1.11	—	10.39	—	8.95
8.05 Al_2O_3	—	—	—	—	8.05	—
4.37 Fe_2O_3	—	—	4.37	—	—	—
1.48 MgO	—	1.48	—	—	—	—
1.25 SO_3	1.25	—	—	—	—	—
98.61	2.12	2.59	7.43	39.48	21.31	25.65

Dutch Embargo on Foreign Cement.

It is announced that the Netherlands Government has issued a decree to the effect that all cement used on public works authorised by the Government must be of Dutch manufacture.

Cement Production in Russia.

It is stated that the production of Portland cement in Russia for the first three months of this year amounted to 791,000 tons, compared with 530,000 tons in the first quarter of 1931.

New Manchurian Cement Plant.

We learn that the new Tsung Tse Cement Works to be erected in Kirin, Manchuria, by the Asano Cement Company will have an annual capacity of 250,000 tons.

Ageing of Cement Under the Influence of the Atmosphere.

By V. M. ANŽLOVAR.

It is well known that exposure to the atmosphere causes changes in cement as a result of which the original strength values are continuously reduced, and the author has investigated this effect during the past two years on two ordinary Portland and two high-strength Portland cements. The four cements, which will be designated A, B, C and D, were each divided into several equal samples, which were stored under different conditions and tested as follows:

(1) Four samples, one of each cement, were packed in air-tight tins which were dated and stored in a dry position in the laboratory.
(2) Four 22-lb. samples were packed in small jute sacks and stored in the same place as samples (1).
(3) One sample of each cement was tested seven days after grinding.
(4) Samples (1) and (2) were sealed after tests (3) were completed, and later tested after 3, 6, 9 and 12 months' storage.

The results of these tests are very interesting, and in general confirm previous investigations. The samples stored in air-tight tins remained completely unchanged even after a year's storage, and there is thus no need to go into the detailed results. They confirm that cement is not affected by storage when well packed in good iron casks.

The samples packed in jute sacks, on the other hand, show important changes, and the results are shortly summarised in the tables.

TABLE I.

Effect of Time of Storage on Setting Time.

Setting Time after Storing for	Normal Cement A.		Normal Cement B.		High-strength C.		High-strength D.	
	Initial.	Final.	Initial.	Final.	Initial.	Final.	Initial.	Final.
	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.
7 days	3 30	5 25	3 0	5 10	2 45	5 30	0 45	2 0
7 days + 3 months ..	3 0	5 20	2 55	6 0	2 55	5 15	1 35	3 20
7 ,, + 6 ,, ..	5 35	7 20	4 0	6 30	3 0	5 40	1 35	3 25
7 ,, + 9 ,, ..	6 25	13 15	8 0	10 50	8 0	14 0	4 45	7 20
7 ,, + 12 ,, ..	5 30	10 20	7 35	13 0	7 10	13 35	5 20	7 15

It will be seen from Table I that the 7-days' old cement has generally the shortest setting time. The 9-months' cement has in certain cases a longer setting time than the 12-months' samples. It is reasonable to conclude that setting time increases with the age of the cement. It may be noted that the setting time of the ordinary Portland cements is less affected by storage than that of high-strength cements.

TABLE II.
EFFECT OF TIME OF STORAGE ON FINENESS.

Fineness (Sieve Residue) after Storing for	A		B		C		D	
	76 Sieve.	180	76	180	76	180	76	180
7 days	0.2	10.0	0.2	9.0	0.1	6.5	0.0	2.0
7 ,, + 3 months ..	0.2	9.0	0.2	9.2	0.1	7.0	0.0	1.9
7 ,, + 6 ,, ..	0.2	8.5	0.3	9.5	0.2	9.0	0.0	1.5
7 ,, + 9 ,, ..	0.3	9.5	0.8	10.5	0.2	7.8	0.0	1.8
7 ,, + 12 ,, ..	0.2	8.6	0.5	8.2	0.1	5.3	0.0	1.9

The results given in Table II are not entirely straightforward. It would appear that the fineness of the cement can change with time of storage. This is probably closely connected with changes in the moisture content of the air, but unfortunately hygrometer readings were not taken during the investigation. The fineness of some cements seems to be reduced owing to the formation of lumps. Lumps were found in the sacks after nine months, although the place in which they were stored was quite dry. At the end of a year the fineness of the cements generally increased, which may be attributed to a breaking up of the cement particles.

TABLE III.
EFFECT OF TIME OF STORAGE ON WATER REQUIREMENTS AND SOUNDNESS.

Time of Storage.	Percentage of Water for Normal Consistency (Vicat).				Le Chatelier Test. Expansion in Millimetres.			
	A	B	C	D	A	B	C	D
7 days	28.5	27.0	28.0	27.0	4.5	2.0	2.5	1.0
7 ,, + 3 months ..	29.5	29.0	27.5	28.5	1.0	2.0	3.0	1.0
7 ,, + 6 ,, ..	30.0	30.0	29.0	29.0	1.0	1.5	1.0	1.0
7 ,, + 9 ,, ..	31.0	31.0	29.0	29.0	1.0	1.0	1.0	0.0
7 ,, + 12 ,, ..	30.0	30.0	30.0	29.5	0.0	0.5	0.0	0.0

Consideration of Table III brings out the following two points :

(1) The quantity of mixing water required for normal consistency increases with the time during which the cement has been stored.

(2) The Le Chatelier expansion decreases with time of storage of the cement, i.e., the soundness of the cement is increased.

TABLE IV.
EFFECT OF TIME OF STORAGE ON LOSS ON IGNITION AND SPECIFIC GRAVITY.

Time of Storage.	Loss on Ignition (per cent.).				Specific Gravity.			
	A	B	C	D	A	B	C	D
7 days	4.60	3.00	1.30	1.10	3.03	3.06	3.09	3.10
7 ,, + 3 months ..	6.75	4.05	2.95	2.55	3.01	3.03	3.07	3.05
7 ,, + 6 ,, ..	8.50	5.10	3.90	4.80	2.97	2.99	3.06	3.05
7 ,, + 9 ,, ..	8.60	5.85	5.10	6.60	2.94	3.01	3.00	3.00
7 ,, + 12 ,, ..	9.50	7.35	6.90	10.25	2.91	2.90	3.00	2.84

The following conclusions may be drawn from Table IV :

(1) Loss on ignition increases with time of storage, and specific gravity is simultaneously lowered.

(2) The loss on ignition of the more finely ground of the high-strength cements shows the greatest increase, while its specific gravity behaves correspondingly. In addition, it may be pointed out that the other chemical constituents become smaller in quantity as the time of storage is increased, corresponding to the increase in loss on ignition ; their proportionate relation one to another remains the same.

TABLE V.

Strength of 7-days-old Cements.

Nature and Time of Storage of Test-pieces.	Tensile Strength, lb. per sq. in.				Crushing Strength, lb. per sq. in.			
	A	B	C	D	A	B	C	D
1 day moist air	—	—	—	405	—	—	—	4,607
1 day air + 1 day water ..	—	—	343	479	—	—	5,005	6,740
1 ,, + 2 ,, ..	265	317	412	498	4,437	4,238	5,788	8,091
1 ,, + 6 ,, ..	314	348	544	587	5,133	5,190	8,191	9,926
1 ,, + 27 ,, ..	371	387	554	636	6,328	6,555	10,438	10,580

Tables V to VII deal with the effect of storing the cements on strength. Table V gives the tensile and crushing strengths of the cements after storage for seven days. In every case these values are represented in Tables VI and VII by 100 per cent. and the strength values of the cements stored for longer periods are given as percentages of these 7-day figures. The percentage losses of strength of the cements on storage are clearly seen in Tables VI and VII, from which the following facts may be learnt :

(1) With increasing time of storage all the cements lose more and more of their initial strengths, both tensile and crushing.

(2) The fall in strength is shown to a less extent by the tensile than by the crushing tests. The tests show that crushing tests give a more satisfactory criterion of the quality of cement than tensile tests. The crushing test should therefore be prescribed in the proposed international specification and the greatest importance should be attached to it.

(3) The fall in strength is in general greater in the case of the high-strength cements (C and D) than with ordinary Portland cements (A and B).

(4) The fall in strength is much greater in the case of the 1-day to 3-days' test-pieces than for the 7-days' and 28-days' test-pieces. The high-strength cements therefore lose more and more of their characteristic property of rapid-hardening as the period of storage increases. It is accordingly desirable that standard specifications for high-strength (rapid-hardening) cements should include minimum strength requirements at one to three days.

TABLE VI.—FALL IN TENSILE STRENGTH RESULTING FROM STORAGE OF CEMENT, EXPRESSED IN PERCENTAGES (VALUES FOR CEMENT STORED FOR 7 DAYS = 100 PER CENT.)

Method of Storing Cement Test-pieces.	Cement A, after Storing for (Days)					Cement B, after Storing for (Days)					Cement C, after Storing for (Days)					Cement D, after Storing for (Days)				
	7	97	187	280	370	7	97	187	280	370	7	97	187	280	370	7	97	187	280	370
1 day moist air	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	100	90.8	83.5	69.4	31.2
1 „ „ + 1 day water ...	—	—	—	—	—	—	—	—	—	—	100	87.1	74.6	53.9	45.2	100	81.9	89.0	74.1	46.6
1 „ „ + 2 „ ...	100	99.4	102.1	90.2	74.0	100	93.2	76.2	70.4	66.8	100	86.2	83.1	65.8	48.9	100	94.5	92.9	76.5	54.5
1 „ „ + 6 „ ...	100	96.8	99.1	100.0	98.6	100	92.6	82.0	85.7	89.8	100	80.6	76.5	68.6	62.1	100	91.0	85.4	76.0	61.2
1 „ „ + 27 „ ...	100	103.8	111.1	117.2	105.3	100	103.3	101.1	103.3	103.3	100	92.8	86.4	87.1	86.4	100	92.1	92.1	89.5	79.6
Mean values	100	100.0	104.1	102.8	93.6	100	99.7	86.4	86.4	86.9	100	86.7	80.1	68.8	60.6	100	90.0	88.5	77.1	54.6

TABLE VII.—FALL IN CRUSHING STRENGTH RESULTING FROM STORAGE OF CEMENT, EXPRESSED IN PERCENTAGES (VALUES FOR CEMENT STORED FOR 7 DAYS = 100 PER CENT.)

Method of Storing Cement Test-pieces.	Cement A, after Storing for (Days)					Cement B, after Storing for (Days)					Cement C, after Storing for (Days)					Cement D, after Storing for (Days)				
	7	97	187	280	370	7	97	187	280	370	7	97	187	280	370	7	97	187	280	370
1 day moist air	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	100	84.5	78.7	44.7	21.3
1 „ „ + 1 day water ...	—	—	—	—	—	—	—	—	—	—	100	84.6	70.1	34.3	24.7	100	75.3	62.8	59.0	23.6
1 „ „ + 2 „ ...	100	69.5	66.9	51.6	46.1	100	79.8	60.7	60.6	51.7	100	78.6	74.2	43.0	27.0	100	78.3	65.2	58.0	30.5
1 „ „ + 6 „ ...	100	78.4	80.6	69.2	62.0	100	80.5	75.0	70.7	48.2	100	72.9	69.2	54.1	42.1	100	75.2	68.2	66.2	48.7
1 „ „ + 27 „ ...	100	78.2	87.8	86.3	83.6	100	86.3	83.0	76.3	55.9	100	77.4	73.9	72.6	60.0	100	86.7	83.4	81.3	65.3
Mean values	100	75.3	78.4	69.0	63.9	100	82.2	72.9	69.2	51.9	100	78.4	71.8	50.8	38.4	100	80.0	71.2	61.8	37.9

Report of the Building Research Board.

The Report of the Building Research Board for the year 1931 (recently issued by H.M. Stationery Office, price 3s. net), contains the following notes on cement research work carried out by the Board.

FREE LIME IN CEMENT.—Comparative studies of normal and rapid-hardening Portland cement marketed in this country and abroad show that modern cements are often characterised by relatively high free-lime contents. The calcium hydroxide probably arises for the most part from the moisture and combined water given up by the gypsum to the cement during grinding. From comparative data available on unground clinkers it appears that this calcium hydroxide is mainly produced from calcium oxide already present in the free condition and not from reaction of the cement compounds. The total free lime content of a cement, both calcium oxide and hydroxide, is therefore to be regarded as present in the clinker as it comes from the kiln.

Part of the lime used in modern cement production is often ineffective in producing cement compounds and in contributing to strength, since it is uncombined after passing through the kiln. There appears, however, to be no relation between the hydraulic modulus of a cement (the molecular ratio $CaO : SiO_2 + Al_2O_3$) and the free lime content; thus high free lime contents may be found in cements with a low hydraulic modulus. While rapid-hardening Portland cements tend to have the higher free lime contents, the order is far from general, and some such cements are found with a low free lime content and a high hydraulic modulus.

STRENGTH TESTS.—Reference was made in the last report to the fact that the present British Standard Specification tensile tests on sand mortars do not give a reliable indication of the quality of concrete made from the cement. A scheme of tests on both normal and rapid-hardening Portland cements was outlined and the results of a few preliminary tests were reported. The primary object of this investigation is to find a small-scale test on a mortar which will yield reliable information as to the strength of concrete made with the same cement. The results will be discussed with this requirement as a basis of comparison. In making comparisons the strengths have been compared at equal ages for all forms of test.

The tests on five different cements have now been completed and, since the differences between the cements are sufficient to cover practically the whole range of the investigation, it is possible to draw certain fairly general conclusions from the results. When the results on the first two cements were complete, it was found that the programme of tests could be reduced for the subsequent cements. The graded sand mortars appeared to have no advantage for testing purposes over ordinary standard sand mortars, and the tests on the former were therefore discontinued. The compression tests on concrete cylinders were also discontinued since they appeared to give no information other than that which could be obtained from tests on cubes.

It is found that the crushing strength of a 1 : 3 standard sand mortar cube having a water/cement ratio of 0.50 is the best guide to the crushing strength of concrete which has so far been obtained. This form of test has the additional advantage that the crushing strength of the mortar is very nearly equal to the crushing strength of a 1 : 2 : 4 concrete made with the same cement and having a water/cement ratio of 0.60, the tests being made at equal ages. Since the crushing strengths of the 1 : 3 standard sand mortars of varying consistence are not definitely related, it follows that the drier consistences of the mortars do not form such a good index of the concrete strength as the wet consistence.

Taken over the whole range of tests, the crushing strength of mortar is a better guide to the crushing strength of concrete than is the transverse test on mortar ; and the transverse test on mortar is better than the tensile test. The tensile test on neat cement is of very little value for this purpose.

Cement Production in Portugal.

For the period January to June 1932 the production of Portland cement in Portugal amounted to 53,764 metric tons, compared with 43,396 metric tons for the same period of 1931.

Separation of Coarse Material from Slurry.

Slurry as it comes from the wet raw-material grinding mills often contains a certain amount of unground oversize material, including flint chips and the like, which not only cause heavy wear of the pumps and delivery piping but also influence adversely the quality of the cement. To eliminate this coarse material from the slurry, the "Universal" oscillating screen ("Schieferstein" System) has been developed by Messrs. Fried. Krupp Grusonwerk.

This screen is a small mechanical appliance requiring little driving power, and in connection with it there has been evolved a method of operation which consists, in the main, of interposing this screen between the primary and fine grinding mills, or, in the case of compound mills, between the primary and fine grinding compartments of the wet grinding mills. By this method the slurry flowing out of the primary mill is led over the screen, the coarse material passing clear, whilst the slurry thus freed of such material is screened and passes into

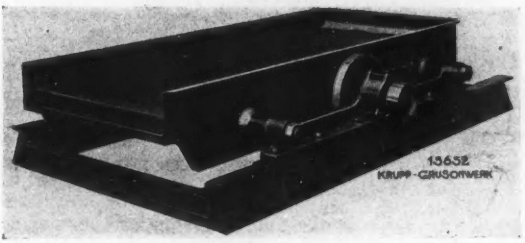


Fig. 1.

the fine-grinding mill, or, in the case of compound mills, into the fine-grinding compartment. In this manner the fine-grinding mills or fine-grinding compartments of compound mills receive a uniform and fine product, and can therefore be filled with smaller and thus more effective grinding media so that the output of the mills may be increased. After the elimination of the coarse material the slurry can be dealt with by an ordinary pump.

The machine is so designed that no vibrations are transmitted by the frame to the building in which it is installed. The screen works with circular oscillations of an amplitude or throw of 0.06 to 0.1in. (1.5 to 2.5 mm.) off centre at a speed from 1,500 to 2,000 oscillations per minute so that maximum screening action is obtained. At every point over its area the screen has the same movements as the screen box, so that the wire composing the screen mesh is relieved of bending stresses, while, due to the screen movement, wear of the screen wire cloth by friction with the material being treated is negligible.

The screen box is supported on four rubber buffers located on two cross-members, and this arrangement, combined with the correct balancing of the oscillating forces, ensures an unobstructed performance of the motion imparted

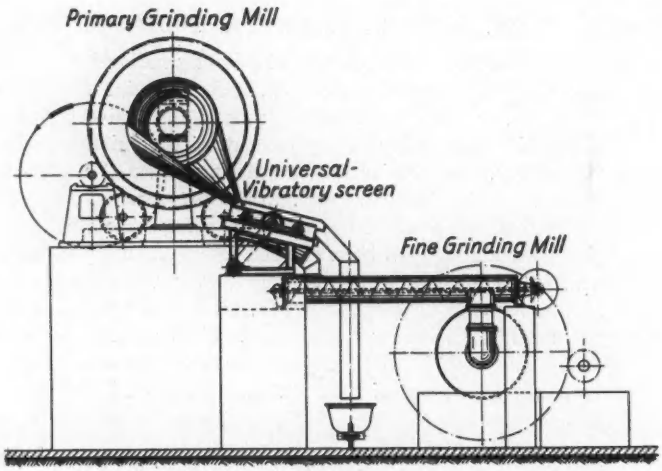


Fig. 2.

to the screen. Running in heavy pendulum roller bearings, the driving shaft rotates with its end journals concentrically in the machine frame, so that the belt pulley turns about a definite axis and does not execute any oscillatory movement.

These screens are available in the following standard sizes of screening area: 2ft. by 4ft. 11in., 2ft. 8in. by 6ft. 7in., 3ft. 3in. by 8ft. 3in.

The construction of the screen is shown in Fig. 1. With a screening area of 2ft. by 4ft. 11in. the capacity per hour is as follows: mesh 0.04 by 0.157in., 30 to 40 tons; mesh 0.02 by 0.157in., 15 to 20 tons. An installation of the machine in existing plants is shown in Fig. 2, from which it will be seen that no great expense is entailed.

The Cement Industry in Syria.

The following is taken from a recent report by H.M. Consul-General at Beirut: "In the Lebanon the most important industrial enterprise is the cement factory at Ras Shekka, between Beirut and Tripoli, built by the Société des Ciments Libanais. The capital invested is said to be 21 million French francs (£169,068). The present yearly output is about 25,000 tons, and the possible maximum double that amount."

Cement Production in Canada.

For the month of July last the production of Portland cement in Canada amounted to 242,931 barrels, compared with 506,446 barrels in July 1931.

Notes from Abroad

Cement Production in the United States.

For the first six months of this year the production of cement in the United States was 34,156,000 barrels, compared with 60,133,000 for the first half of 1931 and 75,894,000 in 1930. For the twelve months ending June last production was 36.5 per cent. of capacity, against 65.4 per cent. and 81.4 per cent. in 1931 and 1930 respectively. For the month of June only production was 35.7 per cent. of capacity, against 55.2 per cent. in 1931 and 66.4 per cent. in 1930.

Cement Production in Japan.

It is reported that the Cement Rengokai has increased the curtailment of the production of Portland cement from 56 per cent. to 57.5 per cent. for the period September to November 1932.

Cement Production in Russia.

It is reported that the production of Portland cement in the U.S.S.R. for the first six months of this year was 10,027,000 barrels.

Cement Company's Meeting.

Ketton Cement Company, Ltd.—The annual meeting of the Ketton Portland Cement Co., Ltd., was held last month.

Mr. Joseph Ward, J.P., who presided, said that in view of the fall in cement prices and the unprecedented period of commercial depression through which the country had passed, the Directors felt satisfied with the results achieved during the past year.

The net result of the year's working, after providing for directors' fees and taxation, was a profit of £29,015, which, added to the carry forward of last year (£2,174) gave a total of £33,189 for disposal. An interim dividend of 3¾ per cent., less tax, for the six months ending December 31, 1931, was paid on March 31 last on the 7½ per cent. participating preference shares, and 2½ per cent., less tax, on the ordinary shares, and the twelve months' dividend, to June 30, on the 6 per cent. cumulative first preference shares, totalling £7,633 16s., and leaving £25,555 19s. 8d. for disposal. They recommended the payment of a final dividend of 3¾ per cent. on the 7½ per cent. participating preference shares, and a dividend of 2½ per cent. on the ordinary shares, making 5 per cent. for the year, both less tax.

The overwhelming depression was naturally affecting the cement industry. It was a serious question, demanding a searching inquiry, whether the severe economy campaign of the Government was not being carried far beyond its economical limit.

The cessation of public works on road construction and maintenance, buildings, housing and sewage, and other schemes, had not only reduced considerably the demand for material, but had added very large numbers to the ranks of the unemployed, involving heavy additional payments for which the country did not receive any return.

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Trade Notices.

Vibrating Screens.—Messrs. Edgar Allen & Co., Ltd. of Sheffield, have recently published a brochure on Edgar Allen—Allis-Chambers centrifugal vibrating screens. These are used for screening and sizing lump and granular substances such as crushed stone, all kinds of ore, coal and coke. Attention is drawn to the following features: driving mechanism above screen; screen and frame easily replaceable; all revolving parts enclosed; plant may be suspended from overhead or spring mounted from beneath. Copies will be sent to those interested.

An Excavator Contract.—Messrs. Ruston-Bucyrus, Ltd., of Lincoln, have received an order for five electrically-operated excavators, equipped as shovels with buckets of 1 cub. yd. capacity, from the Crown Agents for use on the new civil aerodrome at Singapore. The machines will be fitted with rope thrust to control the thickness of cut and working radius; this control gear enables the bucket to be vigorously shaken to clear itself of the sticky clay with which the machines have to deal.

Dutch East Indies.

A trading profit of £33,655 was made by Nederlandsch-Indische Portland Cement Maatschappij for the year 1931, against £67,695 for 1930.

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